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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 117.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE RED SPIDER ON HOPS IN THE SACRAMENTO VALLEY OF CALIFORNIA.

BY

WILLIAM B. PARKER, M. S.,
Entomological Assistant.

ISSUED MAY 3, 1913.

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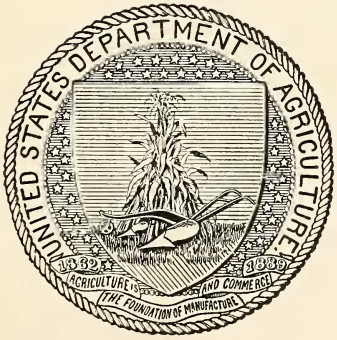

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., November 15, 1912.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 117 of the Bureau of Entomology, a manuscript entitled "The Red Spider on Hops in the Sacramento Valley of California," by William B. Parker, an entomological assistant in this bureau.

This manuscript deals with a pest the study of which has been hitherto largely neglected and which of recent years has attracted much attention from an economic standpoint, on account of immense losses to growers of hops and other crops in the Pacific coast region and elsewhere.

Mr. Parker's studies, as outlined in this paper, have added considerably to the knowledge of the habits of this pest and have shown methods by which it may be economically controlled.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE RED SPIDER ON HOPS IN THE SACRAMENTO VALLEY OF CALIFORNIA.

INTRODUCTION.

The common "red spider" (*Tetranychus bimaculatus* Harvey) has long been known as a pest in flower gardens and greenhouses, where it is often very injurious on ornamental plants. This damage, however, becomes quite insignificant when the injury to hopvines is considered. During the past few years this mite has become recognized as one of the most injurious of hop pests on the Pacific coast and especially so in the Sacramento Valley of California.

The investigation upon which this bulletin is based was begun January 1, 1911, at the request of the horticultural commission of Sacramento County and in cooperation with the E. Clemens Horst Hop Co., of San Francisco, and extended over a period of 18 months. Observations were made throughout this period in the hop fields in all parts of the Sacramento Valley, and spraying experiments were conducted on both a large and a small scale.

The recorded efficiency of the various insecticides tested during this investigation is based upon actual counts of mites present before and after spraying, as well as upon general observations under ordinary field conditions.

ECONOMIC IMPORTANCE.

The red spider was reported in injurious numbers in the hop fields at Wheatland, Yuba County, Cal., in 1902. Since then it has done some injury to hops in the Sacramento Valley every year and in 1910 the hop crop was seriously injured in many localities. One company, the E. Clemens Horst Co., estimated their financial loss due to this mite in a few of their hopyards near Sacramento, Cal. (allowing 14 cents per pound for hops), to be from $10 to $68 per acre. Other growers were not able to pick their hops so rapidly as did this company, and their loss was necessarily much greater. In some yards near Sacramento the hops were so badly injured that they could not be picked at all and were allowed to remain in the field.

NOTE.—Obligations are due to the manager of the E. Clemens Horst Co. and to the superintendent of the ranches at Perkins and at Wheatland, who placed at my disposal every means possible to carry on the work; to Prof. W. B. Herms, for many valuable suggestions; to Mr. E. K. Carnes, superintendent of the State insectary, Sacramento, Cal., who generously provided me with desk room; and to Dr. F. H. Chittenden, under whose directions the investigation was carried on.—W. B. P.

An extract from a letter from a former hop grower in Washington State describes conditions there as follows: "The 'red spider' was here in 1901, but did little damage. It gradually increased until 1905, when we let 25 of 85 acres blow away and what we did bale was trash. Then we gave up the fight."

The red spider is reported to have been very destructive to hops at Agassiz, British Columbia, but for the past few years has not appeared in injurious numbers.

The past seasons were very late, and the mites were not present in noticeable numbers in the hop fields near Sacramento until the middle of June. Even so, they had done much damage by August, 1911, and if the crop had not been promptly and rapidly picked many of the hops would have "blown away," resulting in the total loss of a great portion of the crop.

FIG. 1.—The red spider (*Tetranychus bimaculatus*): Egg (position indicated by white circle) among webs on surface of leaves. Greatly enlarged. (Original.)

LIFE HISTORY.

THE EGG.

Description.—The eggs of *Tetranychus bimaculatus* (fig. 1) are small, spherical, pearl-like objects, about one-sixth of a millimeter in diameter, though somewhat variable in size. From 10 to 450 are usually present on a leaf, and with the aid of a hand lens they are readily found upon infested foliage.

Where laid.—The eggs are deposited singly and are promiscuously distributed among the webs and upon the underside of the leaves. They are not attached to the host plant by protecting webs, as are the eggs of the citrus "red spider" (*Tetranychus mytilaspidis* Riley), but are held by strong filaments with which they chance to come in contact. Many eggs have been observed on the loose web which is ordinarily spun over infested leaves.

Incubation.—The incubation period varies according to temperature and general climatic conditions. In the experiments conducted at Berkeley, Cal., during February, 1912, the incubation period was found to be from 8 to 10 days. This period during May was from 5 to 10 days, with an average of 7.2 days, while in July, 1911, and during some very warm weather in 1912 it was only 4½ days. The relatively higher temperatures of the summer are responsible for this shortening.

THE LARVA AND NYMPH.

Descriptive.—The larva (fig. 2) is a minute, almost globular object, and differs from the adult in the possession of only three pairs of legs. This six-legged condition lasts only during the first stage, i. e., until the first molt, from which the mites emerge as nymphs, with four pairs of legs, and, except for size and the maturity of the sexual organs, similar to the adults. According to C. H. Perkins,[1] the sexual organs appear with the second molt, but copulation does not take place until after the third.

Length of stages.—The length of the larval and nymphal periods varies, being from 8 to 16 days, according to the prevailing temperature. As shown in Table I, this period under the temperature conditions given in the plat was 15 to 16 days. During May, however, this period was found to be 11 to 12 days and in July, 1911, which was an exceptionally warm month, two mites were observed to be mature 8 days after emerging from the egg.

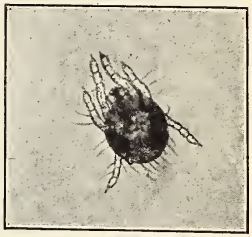

FIG. 2.—Larva of the red spider. The legs in this stage are transparent. Greatly enlarged. (Original.)

Under field conditions in 1911 it was impossible to carry out any very extensive life-history experiments. During the winter, however, a series was carried out in the insectary of the University of California, at Berkeley, Cal.

This series is recorded in Table I.

TABLE I.—*Transformations and length of stages of the red spider in California, 1912.*

No.	Eggs laid.		Hatched.		Length of stage.	First molt.		Length of stage.
	Date.	Time.	Date.	Time.		Date.	Time.	
					Days.			*Days.*
1	Feb. 6	9 a. m.	Feb. 16	8 a. m.	10	Feb. 20	5 p. m.	4⅓
2	6	9 a. m.	15	12 m.	9	20	9 a. m.	5
3	6	1 p. m.	16	3 p. m.	10	20	4 p. m.	4
4	6	3.30 p. m.	16	11 a. m.	10	20	4 p. m.	4⅚
5	7	8 a. m.	16	3 p. m.	9	20	9 a. m.	3¾
6	8	3 p. m.	16	3 p. m.	8	20	9 a. m.	13¼
7	7	9 a. m.	16	3 p. m.	9	21	4 p. m.	5

No.	Second molt.		Length of stage.	Third molt.		Length of stage.	First egg laid.		Total time, egg to adult.
	Date.	Time.		Date.	Time.		Date.	Time.	
			Days.			*Days.*			*Days.*
1	Feb. 25	4 p. m.	5	Feb. 29	9 a. m.	3⅜	Mar. 2	11 a. m.	25
2	25	4 p. m.	5⅓	29	9 a. m.	5⅓	2	11 a. m.	25
3	25	4 p. m.	5	29	9 a. m.	3⅜	.....	.....	.....
4	25	4 p. m.	5	29	9 a. m.	3⅜	2	11 a. m.	25
5	25	4 p. m.	5⅓	.....	.....	.....	2	11 a. m.	24
6	25	9 a. m.	5	29	9 a. m.	4	2	11 a. m.	23
7	25	4 p. m.	4	Mar. 1	11 a. m.	4¾	3	11 a. m.	25

[1] Report of the Vermont Agricultural Experiment Station, 1896–97.

THE ADULT.

Description.—The adults of *Tetranychus bimaculatus* (figs. 3, 4) are small, greenish yellow or, in some cases, reddish mites ranging in size from 0.27 mm. in the male to 0.50 mm. in the female. The abdomen joins the cephalothorax, formed by the fusion of the head and thorax, at its full width and extends over the portion to which the posterior pair of legs is attached. The abdomen, the cephalothorax, and particularly the appendages are well provided with hairs.

FIG. 3.—The red spider: Adult female, dorsal view. Greatly enlarged. (Original.)

The two sexes are very distinct. The female is much the larger and has a broad, rounded abdomen, while in the male the abdomen is narrow and tapering. These differences are so well marked that the sexes may be distinguished under an ordinary hand lens.

FIG. 4.—The red spider: Adult male, dorsal view. Greatly enlarged. (Original.)

Copulation.—Copulation begins as soon as the mites become adult, the female often receiving several males. Contrary to the usual method, however, the male operates from beneath the female. The male mite forces its way under the abdomen of the female, braces its legs against the leaf, and directs the genitalia over its back.

Parthenogenesis.—The idea that parthenogenesis occurs with the red spider is an old one, and during this investigation a few experiments were carried on along this line. A morning-glory (*Ipomœa* sp.) was cleaned of all mites and eggs, the petioles of the leaves were banded with tree tanglefoot, and adult mites were placed upon 10 of the leaves. After eggs were observed the female and all but one of the eggs were

carefully removed from each leaf. When mature the two females that survived upon the isolated leaves were carefully watched to be sure that no male mite reached them. Thirty-three eggs were deposited by these virgin mites and all of the 26 that hatched were males.

HABITS.

HABITATION.

Small numbers of mites were observed during the early summer on the underside of hop leaves. A few strands of web were usually present to begin with, and as the number of mites increased the web became more extensive and was observed frequently to cover, in an irregular manner, the entire underside of the infested foliage. The lower leaves were first attacked, but as infestation increased these leaves, which were severely injured, began to dry and thus forced an upward migration of the mites. By August the entire vines were infested and in severe cases mites were observed upon the surface as well as the underside of the leaves.

PROTECTION.

Inhabiting as they do the underside of the leaves, the mites are well protected from wind and other climatic conditions. Further than this, the web which is spun indiscriminately across the underside of the infested foliage affords the mites much protection. Where the finer mist sprays were used the webs were frequently not penetrated and the mites beneath remained uninjured. This combination of web and leaf affords the mites great freedom from injury. The web of the red spider is spun by either sex, and is at all times carried about by the mite as a guard against falling. It thus becomes scattered over the underside of infested leaves and other objects over which the mites may crawl.

HIBERNATION.

A careful examination, during February and March, 1911, of soil and hop roots taken from fields which were badly injured by the red spider in 1910 failed to reveal any hibernating mites or overwintering eggs. During 1911 the mites were found only upon violets and mallow (*Malva parviflora*) which grew in a flower garden half a mile from the hopyards, but they were observed in considerable numbers the following fall, winter, and spring upon wild morning-glory and mallow in all parts of the hopyards.

It is evident, therefore, that the mites pass the winter upon wild plants in and around the hopyards, as has been found true of the red spider attacking cotton in the Southern States, by Mr. E. A. McGregor of this bureau.

LOCOMOTION.

In order to determine the probable distance that an adult female mite is capable of crawling in one day, experiments were conducted in the laboratory. A sheet of paper 3 by 4 feet was placed in front of a window in a warm room, a female mite placed in the center of the paper, and its progress followed with a pencil for one hour. (See

FIG. 5.—Track of a red spider on blotter, covering a distance of 40 feet 9 inches and representing movements during one hour. Sacramento, Cal., 1912. (Original.)

fig. 5.) In two cases loose soil was placed on the paper. Table II sums up the results.

TABLE II.—*Distance traveled by adult female red spiders in one hour on smooth paper and on loose soil.*

Experiment No.	Surface used.	Distance traveled.	Distance gained.
		Ft. in.	*Ft. in.*
1	Smooth paper	22 4	
2	.....do	23 8	
3	.....do	3 7½	2 0
4	Loose soil		0 11½
5	Blotting paper	20 5	
6	.....do	15 9	
7	.....do	40 9	
8	Packed soil	6 2	
	Average for paper	21 1	
	Average for loose soil		0 11½
	Average for packed soil	6 2	

The surface of the paper corresponds very well with that of the hopvine, and at this rate an average female mite is capable of covering 211 feet of vine surface during a period of 10 hours.

In the case of soil, the lumps and sand interfered greatly with progress and were responsible for many changes in direction. The distance gained by these mites in 10 hours varied greatly, approximating 10 to 60 feet from the starting point. The actual distance traveled over soil may in some cases exceed the above where the soil is very smooth and hard, but on rough ground is probably much less.

From the foregoing experiments it seems probable that the mites can travel some distance over the bare soil, thus infesting plants more or less widely removed from those on which they passed the winter.

EMERGENCE FROM HIBERNATION.

First appearance of mites on hops.—The hopvines in yards that were known to be infested during 1910 were frequently inspected for mites during the following spring. The first mite observed upon a hopvine was found April 21 in the center of a yard near Sacramento. This lone mite was surrounded by eight eggs and protected by a small amount of dusty web. No more mites were observed until May 9, when a single mite was discovered on a hopvine situated 100 feet from a fence dividing two large hopyards near Perkins, Cal. Mites were later found upon some early hops which were growing along a fence and were also present in about the same numbers upon hopvines some distance from the borders of the hopyards. The mites gradually increased in numbers, and by June 1 occasional hopvines were found on which the lower leaves harbored from 5 to 33 mites each.

As is shown by the foregoing data, the mites appeared simultaneously in various parts of the hop fields and did not, as was formerly supposed, invade the yards from along the edges and work toward the center of the fields.

MIGRATORY ACTIVITIES.

Before the infestation became severe the mites were observed upon the underside of the lower leaves, over which they had spun a small amount of web. No distinct migration was noted at this time, but as the mites increased in numbers the infested leaves were seriously injured and partially dried. In this condition they furnished very little food and forced the mites to migrate to fresh foliage, leaving behind them from 100 to 450 eggs and at least one-tenth as many larvæ. Gradual upward migrations continued until the last of July, at which time the plants were entirely infested.

During the month of August a new condition was observed. The morning-glory in the hopyards had become seriously injured by mites. A migration caused by the sudden decrease in the food supply was begun and soon became very extensive. Myriads of mites were seen crawling from the dying morning-glory, over the clods, up the vines and trellis poles, and covering everything with a fine web.

A similar condition was noticed on a few hopvines that had fallen from the wire. The leaves that were farthest from the ground were

covered and often connected by a web which appeared reddish-brown or silvery, according to the number of mites present. The mites were frequently found clustered like swarms of bees (Pl. I, figs. 1, 2), and the lower ones in dropping off were blown several inches by the wind.

That migration did not take place during the early part of the season was evidenced by the fact that 26 vines which were planted that season were noted to be free from mites July 25, 1911, while the surrounding older vines were thoroughly infested. Soon after the migrations commenced, however, mites were seen upon these vines.

FOOD PLANTS.

Tetranychus bimaculatus has a remarkably large number of host plants, and as will be seen from the following list, these plants belong to a wide range of families, including glabrous and hirsute plants. For convenience the following list has been divided into three parts. The first part contains a list of greenhouse and ornamental plants attacked by the mites; the second, a list of plants attacked in the field; and the third, a list of plants which were observed to be infested in and around the hopyards in the Sacramento Valley, Cal.

List of food plants of Tetranychus bimaculatus.

Greenhouse and ornamental plants, etc.—Rose, violet, carnation, mignonette, clematis, pelargonium, abutilon, fuchsia, passiflora, manettia, bouvardia, feverfew, verbena, heliotrope, honeysuckle, hydrangea, salvia, morning-glory, moonflower, cypress vine, phlox, aster, chrysanthemum, dahlia, sunflower, goldenglow (*Rudbeckia* sp.), calla, Easter lily, Boston smilax, mimulus, slipper flower (*Calceolaria* sp.), canary bird vine (*Tropæolum peregrinum*), thunbergia, wedding bells (*Burgmansia arborea*), castor-oil bean, *Asparagus plumosus*, cuphea, godetia, caladium, tomato, cucumber, onion, and sweet pea.

Field plants, shrubs, and trees.—Bean, lima bean, cowpea, pea, cucumber, chayote (*Sechium edule*), cantaloupe, watermelon, squash, celery, eggplant, pepper, tomato, pepino (*Solanum muricatum*), cotton, okra, corn, raspberry, blackberry, table and sugar beets, hops, hemp, alfalfa, clover, peanut, groundnut (*Apios apios*), English ivy, ferns, privet, hollyhock, Kentucky coffee tree (*Gymnocladus canadensis*), wistaria, hop tree (*Ptelea trifoliata*), pecan, ornamental sassafras, cedar, arborvitæ, Colorado blue spruce, maple, horse-chestnut, Carolina poplar, and birch.

Host plants in and near hopyards.—Mat-grass (*Lippia nodiflora*), *Amaranthus blitoides*, hedge mustard (*Sisymbrium officinale*), wild sunflower (*Helianthus lenticularis*), alkali mallow (*Disella hederacea*), *Persicaria lapathiflora* (perennial of *Persicaria*), rough pigweed (*Amaranthus retroflexus*), prickly lettuce (*Lactuca scariola*), blessed thistle (*Cnicus benedictus*), alfalfa (*Medicago sativa*), burdock (*Arctium lappa*), burr clover (*Medicago hispida*), wild morning-glory (*Convolvulus* sp.), and cheese weed (*Malva parviflora*). It has also been observed on Jamestown or Jimson weed (*Datura stramonium*), ironweed, Jerusalem-oak weed, wild geranium (*Geranium memlatum*), and *Ligustrum amurense*.

From the foregoing list it is evident that this mite is nearly omnivorous [1] so far as plant life is concerned, and without doubt there are many other food plants not included in this list.

[1] It is more than likely, since its feeding habits are of a suctorial nature, that this mite will thrive upon nearly any form of vegetation in which the pubescence of the underside of the leaf is not so heavy or luxuriant as to prevent its direct attack upon the leaf tissue proper.

FIG. 1.—FALLEN HOPVINE, SHOWING CHARACTERISTIC SILVERY WEB AND CLUSTERS OF RED SPIDERS (TETRANYCHUS BIMACULATUS), INDICATED BY ARROWS. (ORIGINAL.)

FIG. 2.—FALLEN HOPVINES, SHOWING SILVERY WEB, ON WHICH RED SPIDERS ARE CLUSTERED. (ORIGINAL.)

WORK OF THE RED SPIDER ON HOPS.

FIG. 1.—MALE HOPVINE INJURED BY THE RED SPIDER. (ORIGINAL.)

FIG. 2.—MALE HOPVINE UNINJURED BY THE RED SPIDER. (ORIGINAL.)

WORK OF THE RED SPIDER ON HOPS.

NATURE OF DAMAGE.

GENERAL EFFECT OF MITES UPON FOLIAGE.

These mites feed upon the juices and cell contents which they suck from the tissues of the host plant. This extraction of cell contents usually results in the formation of a light spot at the point where the mite has fed. The presence of mites upon a vine during the early summer is readily detected by these yellow spots in the surface of the leaves. As the mites increase in numbers the leaves become more "speckled," turn yellowish, and when severely injured dry up and fall to the ground. Severely infested vines, at the time that the hop cones are forming, were observed to be very yellow and to lose many leaves.

The decrease in the vitality of the vine, which is the direct result of the attack by mites, produces a premature ripening of the hops. The hop cones in infested yards were much further advanced than those in uninfested hopyards under similar soil and climatic conditions. This premature ripening results in a decrease in yield and a weakening of the roots, tending to decrease the crop of the following year.

RELATIVE EFFECT OF MITES UPON MALE AND FEMALE HOPVINES.

The male vines throughout the season showed more immediate and serious injury than the surrounding female vines. In many cases they were almost entirely defoliated (Pl. II, figs. 1, 2), while the neighboring female vines were but slightly injured.

Some leaves which expanded late in the season on the lower parts of the pistillate vines were thin and papery, appearing identical in texture with the leaves of the male vine, and showed an injury similar to that of the male foliage. This severe injury to the male vines appears to be due largely to the nature of the foliage and not to the presence of a larger number of mites than are found upon the female vines.

EFFECT UPON THE QUALITY OF THE HOPS.

Although the foliage upon the arms of the vines was infested at the time the hops were coming out of the burr, the mites were not observed actually to feed upon them until they were nearly full-sized. No direct injury was noted when the mites were first found upon the cones, but soon reddish-brown spots appeared upon the scales and gradually the natural green and yellow turned to reddish brown, the scales became scraggly, and in severe cases the hop cones became so brittle that they could not be picked. (See Pl. V, fig. 1.)

Even when they can be picked the quality is often severely injured. Dr. W. W. Stockberger, of the Bureau of Plant Industry, reports upon some samples of "spider hops" as follows:

> Of these No. 1 is, I should say, practically unsalable. Not only is the color very poor, but it is not uniform and shows very evidently the red discoloration produced by the activities of the "spider." The aroma is also far from pleasing. The second sample, which showed some damage by the spider, is far from being a first-class hop; it of course is still marketable.

Thus, even though a large crop is harvested its value may be greatly reduced by the injury due to the attack of the red spider.

EFFECT UPON MAN.

Some of the workmen of the hop ranches stated that during hop picking they had been troubled by the mites getting upon their bodies and causing an irritation. This point was investigated; several hundred mites were liberated upon the hands and arms of the writer and allowed to crawl around for 20 minutes. A barely detectable itching was the only sensation observed. The irritation mentioned by the men was probably due to scratches of the hop-vines and not to any irritation caused by mites.

DISTRIBUTION IN THE FIELD.

It was the opinion of some hop growers that the red spider appeared first along the roads and fences and gradually worked into the fields, but observations in several localities did not bear out this point. The mites first appeared within the hopyards and not especially along the borders, and although the increase was rapid, the infestation was evenly distributed.

The dust from the roads collecting on the foliage made the web show very distinctly, and the growers, judging the extent of an infestation by the amount of web that can be seen, would naturally think that the infestation started where the web was most noticeable. This accounts for the erroneous opinion mentioned above.

Mr. W. H. Volck, who made some observations upon the red spider at Wheatland, Cal., in 1902, suggested that since the infestation was so sudden the mites might possibly have traveled through the air on webs, like the "balloon" spiders. To test this point four dozen sheets of tanglefoot fly paper were tacked to the trellis poles in various parts of the infested yards at Perkins, Cal. They were put out in June, 1911, and when collected in September many insects were found embedded in the hardened tanglefoot, but no mites were observed. During the migrations in August mites dropping from

the clusters were blown from 6 to 8 inches from where they would naturally drop, but it is very unlikely that they are carried any distance by any but a very strong wind.

The only probable means of distribution other than the natural migrations are by horses used in cultivating, or by the hands and clothing of the men, and possibly on the bodies of the larger insects found on the hopvines.

PREDACEOUS ENEMIES.

Several predaceous insects were observed destroying red spiders on the hopvines near Sacramento, Cal., but their numbers were insufficient to have any effect upon the infestation. The most numerous predaceous insect was a small anthocorid bug (*Triphleps tristicolor* White). This insect, both in the nymphal and adult stages, was very common in some sections of the yards and was frequently seen feeding on the mites.

Certain small ladybirds have been noticed preying upon this species in infested yards, but were not found in large numbers. Among these are the following:

Scymnus nanus Lec., observed at Sacramento, Cal., July, 1911.
Scymnus marginicollis Mann., observed at the same time and place.
Pentilia sp., found in some infested yards but present only in small numbers.

During July *Chrysopa californica* Coq., in the larval stage, was very abundant and probably did more good than all the rest of the predaceous insects together.

Dr. F. H. Chittenden [1] reports (*Scymnus*) *Stethorus punctum* Lec., *Cecidomyia coccidarum* Ckll., *Aphanogmus varipes* Ashm., *Chrysopa rufilabris* Burm., and (*Thrips*) *Scolothrips sexmaculatus* Perg. as feeding upon the red spider at Washington, D. C., and elsewhere.

Mr. E. A. McGregor,[2] an agent of this bureau, has recorded the following natural enemies of the red spider on cotton at Batesburg, S. C., in 1912:

Triphleps insidiosus Say.
Chrysopid larvæ.
Euthrips fuscus Hinds.
Euthrips occidentalis Perg.
Scolothrips sexmaculatus Perg., recorded by both Pergande and Duffy.
Coccinella 9-notata Hbst. (larvæ).
Hippodamia convergens Guer. (larvæ).

While predaceous insects destroy many of the mites in the hop fields, their work has no appreciable effect upon the infestation.

[1] The common red spider, Cir. 104, Bur. Ent., U. S. Dept. Agr., 1909.
[2] The red spider on cotton, Cir. 150, Bur. Ent., U. S. Dept. Agr., 1912.

EXPERIMENTS FOR THE CONTROL OF THE RED SPIDER.

METHODS OF EXPERIMENTATION.

The sudden and widely distributed appearance of the red spiders in the hopyards, the rapidity of their increase, and the fact that the old remedy (sulphur) had not controlled the mites in the hopyards during the preceding season made the control problem appear a difficult one. As soon as the mites became numerous enough on the hopvines to warrant experimental work, the first of a long list of experiments which was planned during the spring of 1911 was applied. The lime-sulphur solutions, because of their efficiency and relatively low cost, soon became the most promising of the contact insecticides. They were therefore applied more extensively and were given more attention than the other materials which were listed during the investigation.

The materials were applied, except in the small-scale work, with a power outfit (Pl. III, fig. 1) which maintained from 120 to 150 pounds pressure. Seven-foot rods tipped with a nozzle throwing a fine but washing spray were used for the work.

In making the tests with the various insecticides it was found desirable to express their efficiency with as near an approach to numerical exactness as possible. Tag counts and field counts were employed in obtaining the percentage of mites killed and were found to be very accurate. In most cases only one of these methods was used on a plat, but occasionally both were employed. These counts were made both before and after spraying.

Tag counts.—Twenty tags were attached to the petioles of as many leaves, and the numbers of mites found upon the several leaves, both before and after spraying, were recorded upon the attached tags. The percentage of mites killed by the spray was thus very accurately obtained.

Field counts.—Field counts were made by picking 20 leaves from various parts of as many vines chosen throughout the plat. The numbers of mites found upon the leaves, which were taken both before and after spraying, were compared and the precentage of mortality obtained. This method gave a good idea of field conditions but did not prove as effective as the tag count.

SULPHUR.

Sulphur in a dry and finely divided form has in past years been used very extensively against red spiders with supposedly good results. One experimenter states that although the sulphur does not affect the adult mites, it kills the larvæ when they emerge from the eggs and thus checks the infestation. Several hop growers stated that the red

FIG. 1.—SPRAYING HOPVINES WITH POWER OUTFIT. (ORIGINAL.)

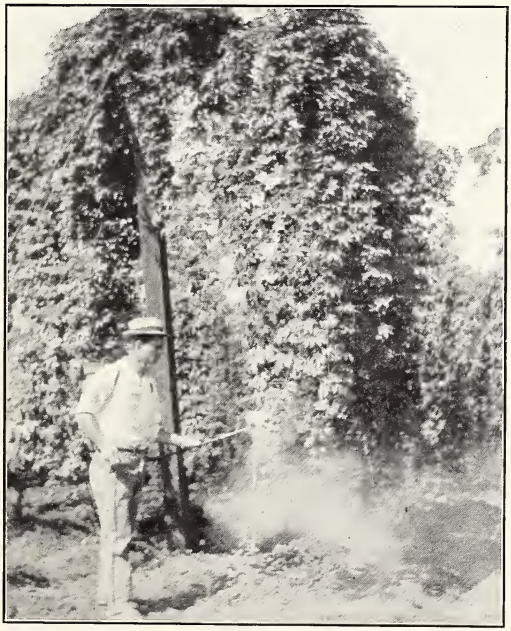

FIG. 2.—APPLYING PRECIPITATED SULPHUR IN DUST FORM AS A REMEDY AGAINST THE RED SPIDER. (ORIGINAL.)

SPRAYING AND DUSTING FOR THE RED SPIDER ON HOPS.

FIG. 1.—SWEET PEAS INFESTED BY THE RED SPIDER, BUT PROTECTED BY DUSTING, AT INTERVALS OF ONE WEEK, WITH PRECIPITATED SULPHUR. LOS ANGELES, CAL., 1910. (ORIGINAL.)

FIG. 2.—SWEET PEAS, GROWTH ABORTED, BLOSSOMS INDIFFERENT, AND VINES NEARLY KILLED BY THE RED SPIDER. LOS ANGELES, CAL., 1910. (ORIGINAL.)

THE RED SPIDER ON SWEET PEAS.

spider could be easily controlled; that sulphur dusted or blown onto the vines would soon check their progress. General observations made in the infested fields that were thoroughly dusted with finely powdered sulphur, however, lead the writer to believe that dry sulphur is of no value whatever in checking the ravages of this mite upon hops. This point was most conclusively proved, as will be seen from the following data.

In testing the efficiency of this material upon the mites, all the available forms of dry sulphur were purchased and a precipitated form was prepared by treating a lime-sulphur solution with hydrochloric acid. These sulphurs were applied in the form of dust (Pl. III, fig. 2) and also with water as a "wet spray." Table No. III gives results which were obtained from tag counts taken at various times during the season of 1911 and 1912.

TABLE III.—*Negative results produced by sulphur in various forms used against the red spider on hops.*

Date.	Material.	Number of mites present before.	Number of mites killed by application.	Per cent of mites killed by application.	Days between application and third count.	Number of mites, third count.	Increase of mites.	Per cent of increase.
1911.								
June 30	Precipitated sulphur, 10 pounds; flour paste, 4 pounds; water, 100 gallons	271	.....	.....	10	282	11	4.06
July 15	Flowers of sulphur, 20 pounds; water, 100 gallons	201	61	69.7	26	1,458	1,257	625.00
18	Precipitated sulphur, 10 pounds; water, 100 gallons	264	146	55.3	21	1,533	1,269	480.68
18	....do	305	163	53.4	(1)	(1)	(1)	.....
25	Precipitated sulphur dust, applied dry	560	.....	.....	21	670	110	19.64
1912.								
July 10	Precipitated sulphur dust	638	.....	.....	30	1,198	560	87.77

[1] Tags lost after second count.

Mites of all ages (larvæ, nymphs, and adults) were observed from time to time on the tagged leaves.

This table definitely illustrates the inefficiency of sulphur in controlling the red spider on hops. It will be noted that a certain percentage of mites was killed or washed off by the spray, but the increase which followed proves definitely that sulphur in the dry form has little or no effect upon the mites. Observations in fields where sulphur had been applied by hand and by a traction dust machine also bore out this statement. In some cases there were few mites upon the sulphured vines, and growers claimed that the sulphur had destroyed the mites. Near-by unsulphured foliage, however, was invariably found to be as free from mites as the "sulphured" vines, and this assumption did not hold.

Sulphur as a control of the red spider on hops has been tested and found wanting and is superseded by the contact insecticides.

Reason for inefficiency.—Some experiments with sulphur upon *Tetranychus bimaculatus* attacking prune, pumpkin, and sweet peas proved very satisfactory. Similar results were obtained when sulphur was applied to infested sweet peas in Los Angeles, Cal., by Mr. H. M. Russell, as is shown in Plate IV, figures 1 and 2. The efficiency of sulphur against the red spider on these plants and its inefficiency when applied on hops and cotton led to some careful observations as to conditions. It was noted that the pumpkin and sweet peas expose nearly all of both surfaces of their leaves to the direct rays of the sun at some time during the day and that the mites on the prune were attacking the upper and therefore the exposed surfaces. The hopvines and cotton plants, however, expose principally the upper surfaces of the leaves to the sun and the mites living upon the undersides are thus protected.

From these observations it is evident that sulphur is effective upon the red spiders only when the infested surfaces of the plant are exposed to direct sunshine at some time during the day or to intense reflected heat.

LIME-SULPHUR SOLUTIONS.

The results obtained in a small preliminary field experiment in which lime-sulphur in combination with nicotine sulphate, 40 per cent, was applied gave such good results that these materials were at once placed at the head of the list of sprays to be fully tested out during the course of the investigation. The lime-sulphur solutions are much cheaper than the nicotine solutions when used at the summer dosage; therefore it seemed desirable to try the lime-sulphur solution alone in order to reduce the cost of spraying, provided the omission of the more expensive nicotine solution did not alter the results.

During the early work with these sprays it was evident that the straight lime-sulphur solutions, instead of spreading out in a film, formed beadlike drops on the foliage. Mites found in actual contact with these drops of spray were seen to draw away from them and escape uninjured. The results obtained with straight lime-sulphur solutions were most unsatisfactory.

Soap formed a precipitate with the polysulphid, and as it was very evident that some "spreader" must be used if the lime-sulphur solutions were to prove effective, this subject was thoroughly investigated.

Upon the suggestion of Prof. A. L. Quaintance, of this bureau, "black-strap" molasses, a cheap grade, was used with the lime-sulphur spray at the rate of 2 gallons to 100 gallons of spray. This

mixture spread more rapidly than the straight solutions, but did not prove entirely satisfactory.

While applying a spray composed of lye-sulphur, flowers of sulphur, and flour paste, it was observed that the material spread over the leaves very rapidly. This flour paste seemed to meet the demand for a "spreader" and was accordingly mixed with the lime-sulphur solutions. The result was a smooth mixture, without precipitate, which spread over the leaves in a most effective manner (Pl. V, fig. 2) and gave unusually effective results as an insecticide. The proper proportions were found, on experimentation, to be 4 gallons of flour paste (4 pounds of flour) to 100 gallons of spray.

Lime-sulphur and flour paste proved a very effective and relatively cheap spray for use against the red spider and was extensively used in the control work carried on in the Sacramento Valley in 1911.

TABLE IV.—*Spraying experiments with lime-sulphur solutions against the red spider on hops.*

No.	Date.	Material.	Application.	Number of mites present.	Number of mites killed.	Per cent of mites killed.	Per cent of mites killed after second application.	Cost per 100 gallons.	Count.	Effect on vine.
1	June 23	Lime-sulphur, 36° Baumé, 1-75 [1].	Thorough.	360	135	37.5	.....	$0.26	Tag.	None.
2	27	Lime-sulphur, 36° Baumé, 1-75; flour paste, 4-100.	...do.....	698	692	99.0	.....	.35	...do.	Do.
3	July 1	Lime-sulphur, 36° Baumé, 1-50; flour paste, 4-100.	...do.....	697	691	99.0	.....	.49	...do.	Slight injury.
4	5	Lime-sulphur, 36° Baumé, 1-60; flour paste, 4-100.	...do.....	964	945	98.1	.....	.51	...do.	Do.
5	6	Lime-sulphur, 36° Baumé, 1-86; flour paste, 4-100.	...do.....	593	534	90.0	97.1	.32	...do.	None.
6	6	Lime-sulphur, 36° Baumé, 1-86; flour paste, 4-100.	...do.....	593	586	98.8	.....	.32	Field	Do.
7	9	Lime-sulphur, 36° Baumé, 1-100; flour paste, 4-100.	...do.....	906	892	98.4	.....	.29	Tag.	Do.
8	19	Lime-sulphur, 33° Baumé, 1-70; flour paste, 4-100.	...do.....	143	142	99.7	99.7	.38	...do.	Do.
9	19	Lime-sulphur, 33° Baumé, 1-70; flour paste, 4-100.	...do.....	509	440	86.4	92.9	.38	Field	Do.
10	19	Lime-sulphur, 33° Baumé, 1-70; flour paste, 4-100.	Careless...	509	55	10.8	.....	.38	...do.	Do.

[1] The terms "lime-sulphur, 1-75," "flour paste, 4-100," etc., denote 1 gallon of lime-sulphur to 75 gallons of water, 4 gallons of flour paste to 100 gallons of water, etc.

NOTE.—The amount of material necessary per acre varies from 300 gallons in light foliaged hops to 500 gallons in heavy foliaged hops.

Table IV gives an accurate conception of the efficiency of the lime-sulphur-and-flour-paste spray. The percentages obtained in Nos. 1 and 2 of this table represent graphically the relative efficiency of lime-sulphur solutions with and without the flour paste. A great difference in the percentage is again noted in Nos. 9 and 10. In No. 9 the material was thoroughly applied and in No. 10 applied very carelessly. The lower percentages obtained late in the season as compared with the higher percentages secured earlier in the season are due to

the condition and extent of the foliage on the vines. During the early part of the work the foliage was light and could be easily sprayed, while later on it became dense, and thorough work was quite difficult. The results, however, prove the efficiency of the lime-sulphur-and-flour-paste spray in killing the red spider on the hopvine.

FLOUR PASTE.

The efficiency of flour paste as an arachnicide was indicated in the experiment which is recorded under No. 14 of Table VII, but it was not until the summer of 1912 that its value was fully realized. During spraying experiments with nicotine sulphate and flour paste upon the hop aphis it was observed that many of the smaller aphides had become pasted to the leaves. From this data it was assumed that a solution containing a larger proportion of flour paste should be effective against the more delicate aphides and mites, and the following experiments were accordingly conducted upon the red spider on hops:

TABLE V.—*Experiments with flour paste against the red spider on hops.*

Date.	Formula.	Number of mites present.	Per cent of mites killed.	Cost per 100 gallons.
June 18	Flour paste, 8–100	435	100.0	$0.176
June 27	do	781	99.8	.176
July 12	do	452	99.8	.176
Aug. 6	do	882	100.0	.176
Do	do	477	100.0	.176
Aug. 9	do	908	99.8	.176
	Total	3,759	[1] 99.9	
July 16	Flour paste, 10–100	805	99.9	.22
Aug. 6	do	908	99.9	.22
	Total	1,712	[1] 99.9	

[1] Average.

These experiments prove that the flour paste, 8–100 and 10–100, is effective against *Tetranychus bimaculatus*. The spray pastes the mites onto the leaves, but has no effect upon the eggs, and in controlling the mites a second application is necessary.

The neutrality of this spray was proved by the fact that when applied upon the foliage and blossoms of the hop, in proportions as high as 12 gallons of paste to 100 gallons of spray, no injurious effects resulted. When sprayed onto the burrs and delicate hop cones, it did not prevent pollination or injure the appearance of the scales.

When mixed in the spray tank, flour paste has a tendency to settle, and in order to do satisfactory work agitation is necessary. It is,

FIG. 1.—UPPER ROW: LARGE, FULL-SIZED, HEALTHY HOPS. LOWER ROW: SMALL, ROUGH HOPS, SHOWING LOSS IN WEIGHT DUE TO THE RED SPIDER. (ORIGINAL.)

FIG. 2.—LEAF OF HOP, THE LEFT HALF OF WHICH WAS SPRAYED WITH LIME-SULPHUR AND FLOUR PASTE, AND THE RIGHT HALF WITH LIME-SULPHUR ALONE. (ORIGINAL.)

Note that the spray is uniformly distributed on the left half of the leaf; on the right half, however, it is collected in separate drops or patches, owing to the pubescence of the leaf.

however, an effective, convenient, and nonoffensive spray, and the cheapest one that has been successfully used against the red spider.

LYE-SULPHUR.

The lye-sulphur solution (Formula No. 1), used with success against the red spider on the almond by Mr. W. H. Volck, was applied with flour paste and with cresol soap in various proportions. The results of these experiments (Table VI) were obtained from tag counts and are very promising.

The lye-sulphur solution, used with either the cresol soap or the flour paste, was very effective, and when used in the proper proportions did not injure the foliage in the least. It would have been used more extensively in field experiments had not the lye been disagreeable to handle in making up the stock solution. The lime-sulphur on the market at a relatively low figure proved just as effective as the lye-sulphur and, being much more convenient, was preferred.

TABLE VI.—*Spraying experiments with lye-sulphur in various combinations against the red spider on hops.*

No.	Date.	Material.	Application.	Number of mites present.	Number of mites killed.	Per cent of mites killed.	Cost per 100 gallons.	Effect on vine.
1	June 23	Lye-sulphur, 4–100; cresol soap, 1–300.	Thorough.	377	367	97.4	$1.05	Slight injury.
2	June 26	Lye-sulphur, 2–100; sulphur, 15 pounds to 100 gallons; flour paste, 4–100.	...do.....	374	366	97.8	.708	No injury.
3	July 2	Lye-sulphur, 1–100; sulphur, 15 pounds to 100 gallons; flour paste, 4–100.	...do.....	371	361	97.4	.55	Do.
4	July 15	Lye-sulphur, 1–100.....	...do.....	518	458	88.5	.15	Do.
5	...do....	Lye-sulphur, 2–100.....	...do.....	437	384	87.8	.31	Do.

Although the lime-sulphur, or lye-sulphur, and flour-paste solution did not injure the foliage or the blossoms of the hopvines, it did injure the more tender hop cones. The late spraying with lime-sulphur, if practiced, should be completed before the hop cones come out from the burr.

NICOTINE SOLUTIONS AND OTHER MATERIALS.

The nicotine solutions, used with the lime-sulphur, or with soap, or alone, were quite expensive, as may be seen in Table VII. The lime-sulphur and flour paste was so much cheaper and so effective that the nicotine experiments which had been outlined were conducted on a small scale only. The results of these experiments, together with the results of some miscellaneous experiments, are given in Table VII.

TABLE VII.—*Spraying experiments with various combinations against the red spider on hops.*

No.	Date.	Material.	Application.	Number of mites present.	Number of mites killed.	Per cent of mites killed.	Cost per 100 gallons.
1	July 15	Nicotine sulphate, 40 per cent, 1–750..	Thorough, but beaded.	450	263	58.4	$1.66
2	...do.....	Nicotine sulphate, 40 per cent, 1–1,000.	.....do.....	414	376	90.8	1.25
3	...do.....	Nicotine sulphate, 40 per cent, 1–2,000.	.....do.....	762	677	98.9	.62
4	...do.....	Nicotine sulphate, 40 per cent, 1–3,000.	.....do.....	414	263	63.6	.416
5	July 16	Nicotine sulphate, 40 per cent, 1–60....	.....do.....	237	185	78.1	1.08
6	...do.....	Nicotine sulphate, 40 per cent, 1–2,000; lime-sulphur, 1–86.	.....do.....	312	273	87.5	.85
7	...do.....	Nicotine sulphate, 40 per cent, 1–3,000; lime-sulphur, 1–86.	.....do.....	361	280	78.6	.64
8	...do.....	Nicotine sulphate, 40 per cent, 1–750; cresol soap, 1–300.	Thorough, not beaded.	330	225	68.3	2.08
9	...do.....	Nicotine sulphate, 40 per cent, 1–1,000; cresol soap, 1–300.	.....do.....	164	111	67.7	1.67
10	July 17	Nicotine sulphate, 40 per cent, 1–2,000; cresol soap, 1–300.	.....do.....	269	174	64.7	1.04
11	...do.....	Nicotine sulphate, 40 per cent, 1–3,000; cresol soap, 1–300.	.....do.....	201	115	57.2	.83
12	...do.....	Lime-sulphur and nicotine sulphate, 1–50.	Thorough, but beaded.	273	191	70	.....
13	...do.....	Lime-sulphur and 40 per cent nicotine sulphate, 1–50; flour paste, 4–100.	Thorough, not beaded.	163	157	96.3	.....
14	...do.....	Flour paste, 4–100.....	.....do.....	657	444	67.5	.09

PURE WATER.

Spraying with water is one of the most successful and most commonly used methods of controlling the red spider in greenhouses. With a strong but fine stream of water the mites are washed from the foliage of infested plants and the infestation is reduced to a minimum.

It was thought possible to wash the mites from the hop leaves by spraying water through a coarse nozzle at 200 pounds pressure with about as successful results. This experiment was accordingly carried out, and although some of the mites were washed off, many were left and were later seen to have been uninjured by the force of the spray.

The lime-sulphur-and-flour paste and the flour paste, 8–100, are so cheap that even though between 50 and 70 per cent of the mites could be killed by pure water, one of the former materials, which destroys about 98 per cent, is preferred.

VALUE OF A SECOND APPLICATION.

After a few spraying experiments had been conducted it was seen that the sulphur, the lime-sulphur, and the lye-sulphur had no effect upon the mites except by actual contact; therefore the idea of placing a material on the vines which would kill the larvæ on emergence was abandoned. Although nearly 100 per cent of the mites living upon the leaves could be destroyed by the spray, the eggs were uninjured and the newly hatched larvæ reinfested the leaves as badly as before. It was therefore decided to spray a second time after all the eggs had hatched and yet early enough to prevent any larvæ from becoming mature.

During July the mites passed from larva to adult in 8 days and during April the incubation period was 7 to 10 days.[1] Basing the time of a second application on this data, 7 days was decided upon as the interim between the first and second sprayings, and by following out this plan some very encouraging results were obtained, as shown in Table VIII.

TABLE VIII.—*Experiments showing value of a second application in spraying for the red spider on hops.*

No.	Date.	Material.	Application.	Number of mites present.	Number of mites killed.	Per cent of mites killed.	Second application, per cent killed.
1	July 6	Lime-sulphur, 36° Baumé, 1–86; flour paste, 4–100.	Thorough.	593	543	90	97.1
2	July 19	Lime-sulphur, 33° Baumé, 1–70; flour paste, 4–400.	.....do.....	143	142	99.7	99.7
3	...do.....	Lime-sulphur, 33° Baumé, 1–70; flour paste, 4–100.	.....do.....	509	440	86.4	92.9

It will be noted that only from 0.3 to 7.1 per cent of the original number of mites present on the vines were present after the second application. The mites which hatched from the few eggs that remained were not sufficient to form the basis for a reinfestation and the work was accordingly considered satisfactory.

Unfortunately some of the plats treated were covered with infested morning-glory vines, which were severely injured by the mites, and which later resulted in a migration that soon reinfested the hop-vines. Morning-glory was not present in one plat, however, and although the applications were made so late that the vines were severely injured, the results to be expected from such a plan were clearly proved. These vines were comparatively free from mites at the end of the season and had a much more healthy color than the vines in the adjoining plats which were used as checks.

FORMULAS FOR SPRAYS.

To prepare the flour paste, mix a cheap grade of wheat flour with cold water, making a thin batter without lumps; or wash the flour through a wire screen with a stream of cold water. Dilute until there is 1 pound of flour in each gallon of mixture. Cook until a paste is formed, stirring constantly to prevent caking or burning. Add sufficient water to make up for evaporation. (See Pl. VI, fig. 1.)

For spraying with flour paste alone, use 8 gallons of paste as prepared above to each 100 gallons of water.

For the flour-paste and lime-sulphur spray, use 4 gallons of paste to each 100 gallons of spray containing the lime-sulphur.

[1] In moderate weather allow 10 and in hot weather 7 days between applications.

BANDING WITH TANGLEFOOT.

Banding with tanglefoot has become the chief method of controlling the hop flea-beetle (*Psylliodes punctulata* Melsh.) in British Columbia, and as the mites also work up the vine mainly by crawling it was deemed advisable to attempt to check their progress by means of the tanglefoot bands. In order to test this method, 10 infested hopvines were selected. A few leaves were removed to prevent bridging, and in some cases the vines were stripped; tree tanglefoot was then applied to the vines in 3-inch bands. (See fig. 6.) About 20 badly infested leaves were next attached to the vines below the bands and the lower parts thus thoroughly infested. During the following week these vines were continuously observed. Hundreds of mites were found around the lower edges of the bands, and in cases where the lower leaves had been stripped off some web was found at the base of the tanglefoot, but there was no evidence that the mites had crossed over. Although mites were seen above the bands, these probably were carried there on the observer's hands during previous observations.

FIG. 6.—Hopvines banded with tanglefoot, in an attempt to prevent the mites from ascending. (Original.)

Similar experiments were conducted in 1912, except that some foliage was left below the bands on which the mites could multiply and from which they could migrate. Three weeks' observation failed to reveal mites above properly banded vines, but after this time the tanglefoot became filled with sand and was not effective.

One large-scale experiment with tanglefoot was attempted, but the work was done so late in the season that a few mites were already above the point of banding and no definite results could be obtained.

Banding with tanglefoot in itself will probably not act as a control for the red spider, but in yards where late clean culture is not practicable it will probably protect the sprayed vines from the late summer migrations.

Application.—It is necessary to get the tanglefoot well into the spaces between the two vines, the simplest way to accomplish this

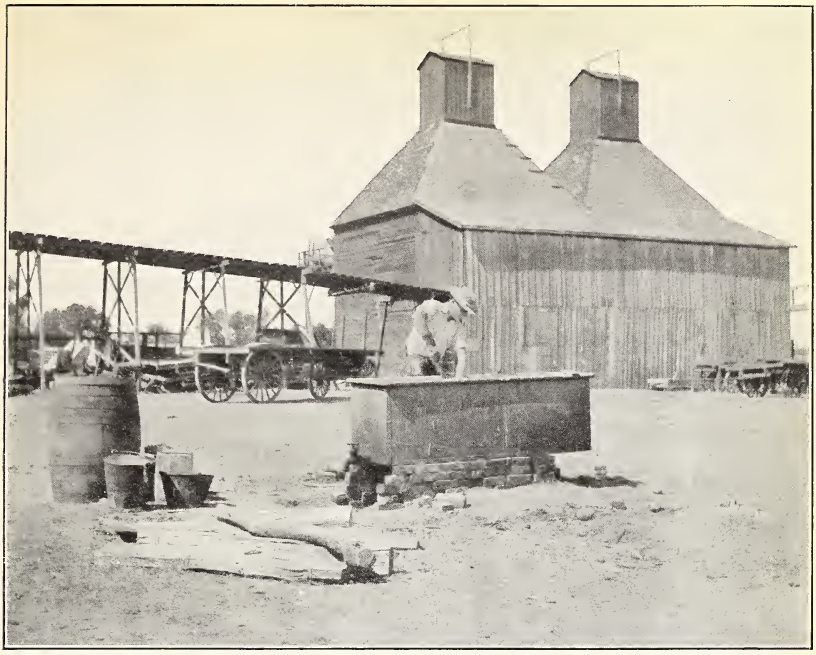

FIG. 1.—COOKING FLOUR PASTE OUT OF DOORS; KILN-HOUSE FOR DRYING HOPS, PREPARATORY TO BALING, IN DISTANCE. (ORIGINAL.)

FIG. 2.—LARGE POWER SPRAYING OUTFIT, SHOWING LINES OF HOSE RUNNING INTO HOPYARD. (ORIGINAL.)

SPRAYING FOR THE RED SPIDER ON HOPS.

being with the hands. A section about 3 inches long should be coated with the tanglefoot, care being taken that no parts are missed and that no leaves are left to form a bridge across it. Although the tanglefoot is apparently very disagreeable material to apply, it is easily washed off the hands with a little kerosene or even with soap and hot water.

METHODS OF APPLYING SPRAYS.

No spraying for the red spider should be attempted unless the proper appliances and machinery are at hand. Hand pumps which will maintain 150 pounds pressure can be used, but power outfits are preferable. Traction and compressed-air sprayers which will maintain the proper pressure are light, convenient, and readily hauled through the hopyards, but unless the required pressure is maintained they will not give satisfactory results in spraying. The outfits used in the experimental work at Sacramento were composed of a gasoline engine, a spray pump, and a 50-gallon barrel mounted upon a light three-wheeled truck. These outfits did effective work, but carried so little spray material that they required refilling entirely too often. A large orchard power outfit (Pl. VI, fig. 2) equipped with two 150-foot lines of hose was operated around the edges of some of the yards with good results. The driver assisted the rodmen in getting the hose in and out of the rows and a wide strip around the yards was treated. In cases where the infestation appears on one side of a field such machines can be readily employed.

The mites are almost entirely found on the underside of the leaves, and in order to wash them thoroughly the spray must be directed from below. When angle nozzles are not available the spray rod may be bent so that the spray may be readily directed to the underside of the leaves. If one or the other of these methods is not employed the material will not be satisfactorily applied.

In order to penetrate all of the webs and reach all of the mites it is necessary to use a nozzle that will throw a washing rather than a mist spray. The Bordeaux or "stopcock" type is usually too coarse and wastes material, so that a nozzle should be chosen somewhere between that and the Vermorel type. Some of the recent makes can be regulated by the alteration of the size of the opening in the disk so that any degree of spray can be obtained. Such nozzles are very well adapted to the red-spider work.

In controlling the red spider in the hop fields it is necessary that a large territory be covered in a short time and that the material be applied very thoroughly. To do this several outfits are necessary and these must be in good working condition. Disabled machinery not only increases the expense of spraying but reduces the chance of controlling the mites.

COST OF SPRAYING.

The following estimate of the cost of spraying for the red spider is made from data taken from actual field work on high-trellis yards. The amount of material needed for hops on short poles will be somewhat less.

It has been found that one machine will spray from 2 to 3 acres per day and that in order to do thorough work it is necessary to apply from 300 to 500 gallons per acre, according to the amount of foliage on the vines. The following data are based on a machine which will spray 2 acres per day.

TABLE IX.—*Cost of spraying hopyards for the red spider.*

	Cost of application per acre.			
	Flour paste, 8–100; cost and cooking, 19 cents per 100 gallons.		Lime sulphur, 1–100, and flour paste, 4–100; cost per 100 gallons, 26 cents.	
	300 gallons.	500 gallons.	300 gallons.	500 gallons.
Labor: 3 men at $2 per day for one-half day	$0.57	$0.95	$0.78	$1.30
1 horse at $0.50 per day for one-half day	3.00	3.00	3.00	3.00
	.25	.25	.25	.25
Total cost	3.82	4.20	4.03	4.55
Cost of two applications	7.64	8.40	8.06	9.10

The cost of stripping the vines preliminary to spraying will be from $1.80 to $2 per acre.

Comparing the cost of spraying for the red spider with the loss that may result from its ravages, it is evident that money spent in controlling this mite will be well invested.

CULTURAL METHODS.

Stripping the vines.—The practice of stripping the vines is a common one in regions where the hop aphis (*Phorodon humuli* Schrank) is troublesome. A large amount of aphis-breeding foliage is cleared from the vines and only the more readily sprayed leaves are left.

In experimenting along this line several vines were stripped and tied together at various points to determine which method would most readily facilitate spraying. The lower foliage on vines which were not stripped but were tied together 4 feet from the ground (fig. 7) was found to be matted and very difficult to spray thoroughly. When the lower 3 feet of the vines were stripped and the two vines tied at the 4-foot mark (fig. 8), 1 foot of the vine was still in a condition difficult to spray. But when stripped and tied a few inches below the lower leaves (fig. 9), the vines spread out nicely and the

leaves were readily sprayed. It is always difficult to spray thoroughly, and any cultural method which will facilitate effective work is worth while. During the early part of the seasons of 1911 and 1912 the mites were observed upon the lower leaves only and from there migrated upward. It is estimated that the stripped area contains about 40 or 50 leaves; taking the average number of mites as 42

FIG. 7.—Hopvine tied high and not stripped; lower leaves difficult to spray. (Original.)

per leaf for an average infestation, the theoretical number of mites that would be removed would be about 1,680 or 2,100 per vine.

One hopyard which was stripped before the mites were above the point to which the vines were to be stripped was observed August 9. It was found that the infestation had been materially checked.

It is believed that timely stripping of the vines and removal and burning of the infested leaves will severely check the infestation and in some cases where the yards are not filled with food plants will

successfully control the mites. Too much faith should not be placed in this operation, however, as spraying may have to be resorted to as a final measure. The cost of stripping is about $2 per acre and is more than offset by the results obtained.

Irrigation.—Vines which have not a large supply of moisture dry and change color more rapidly than those growing in moister soil, so that the work of the red spider is most noticeable on light soil in

FIG. 8.—Hopvine tied high and stripped; lower leaves matted and difficult to spray. (Original.)

the drier parts of the hopyards. Several growers, believing that irrigation of the infested vines would counteract the effect of the mites, pumped water onto their yards and gave the soil a thorough wetting. The vines responded and put out a few fresh leaves, but the mites infested these in the same manner as before and reduced the quality of the hops in the same proportion as on unirrigated and equally infested parts of the adjoining hopyards. Irrigation will not control the mites, but when the soil lacks sufficient moisture it will

stimulate the vines, causing them to put out some fresh foliage so that the loss in weight of the hops will not be so great as it would be otherwise.

Fertilization.—In parts of the hopyards where the vines were very vigorous, as a result of fertilization, the presence of mites was not so noticeable as in parts where the foliage was not so dense. The increase of mites was just as rapid, however, and at the end of the season the densely foliaged vines were just as badly injured, and the

FIG. 9.—Hopvine tied low and stripped; leaves readily sprayed. (Original.)

hops in many cases were discolored. The denser foliage gives a larger surface to be injured, and with equal infestation plats with light foliage will necessarily be more seriously injured than the denser ones.

Fertilization will increase the vigor and the productiveness of the hopvines and, while it will not in any way control the mites, it should be practiced on general principles.

Although the red-spider injury is relatively not so great on vines invigorated by fertilization, it is present and will be extensive according to the severity of the infestation.

Clean culture.—In September, 1911, a block in an infested hopyard was carefully cleared of all vegetation in an attempt to destroy all of the mites present. When examined October 16, however, a few mites were observed on some morning-glory which had come up since the plat was cleared. The practice of clean culture is very important and has a great influence upon an infestation, but it can not be relied upon as a complete control.

GENERAL SUMMARY WITH RECOMMENDATIONS.

The investigation of the control of the red spider on hops has brought out the following points:

Great financial loss may be caused by the red spider.

The mites on hops are *not affected by any form of dry sulphur,* but are readily killed by several contact insecticides, the cheapest and most convenient of which are flour paste (8–100) or a combination of lime-sulphur, 36° Baumé (1–100), and flour paste (4–100). To get the best results it is essential that the vines should be thoroughly sprayed.

Stripping the vines and burning the leaves is an excellent measure, but should not be entirely relied upon as a complete control. When the infestation is severe early in the season and the mites are above the point of stripping, spraying operations should be commenced as soon as the vines are stripped.

The infested area must be *thoroughly and rapidly covered* and must be sprayed a second time, 7 or 10 days later.

Banding with tree tanglefoot will check migrations and is recommended where the hopyards are infested by food plants of the red spider.

Two later spray applications may be necessary if the mites again appear in injurious numbers.

The red spider on the hopvine may be economically controlled if the foregoing measures are carefully carried out.

CONTROL OF THE RED SPIDER UPON PLANTS OTHER THAN HOPS AND COTTON.

The flour paste, 8–100, as described on pages 24 and 27 of this bulletin, is a successful remedy for the control of the red spider in its attacks on all plants except sweet pea, carnation, greenhouse roses, and plants having a heavy pubescence on the leaves. Experiments have been conducted with this material against the mites upon the following plants without the slightest injury to opening buds, foliage, or fruit:

Outdoor plants: Pumpkin, squash, cucumber, roses, violets, box-elder, and bean.

Greenhouse plants: Cucumber, violets, and chrysanthemums.

Judging from the data gathered in the foregoing experiments this spray, when properly used, should control the red spider on all plants except those mentioned in the following paragraphs:

Sweet peas.—The foliage of the sweet pea is very hairy, and that of the carnation and greenhouse rose is so smooth that the flour paste will not stick to it and therefore does not work satisfactorily. The control of mites upon these plants is taken up separately in succeeding paragraphs. The finer forms of sulphur are effective upon the red spider attacking sweet pea (see p. 22) provided that the plants are growing in a warm, sunny place. The sulphur should be thoroughly dusted onto the infested plants, the application being repeated every week or so.

Roses.—Most roses can be sprayed with flour paste, 8–100, but the leaves of roses grown in greenhouses are so smooth and glossy that the paste will not stick to them. The old method of washing them with the garden hose remains as the best remedy in this case.

Carnations.—A weak salt or soap solution is used by some growers as a control for the red spider, but continual spraying with water is the universal method of control.

Use of sulphur.—As stated on page 22, dry sulphur will control the mites upon those plants which expose most of both surfaces of their leaves to the sun during the day, but the flour-paste spray is so cheap, available, and effective that where large areas are involved it is recommended in preference to the sulphur treatment. Sulphur, however, has proved more or less effective upon the squash, pumpkin, sweet pea, and bean.

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